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Publications of the Yerkes Observatory

VOLUME IV PART II

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EDWIN P. HUBBLE

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PHOTOGRAPHIC INVESTIGATIONS OF FAINT NEBULAE[1]

By Edwin P. Hubble

The study of nebulae is essentially a photographic problem for cameras of wide angle and reflectors of large focal ratio. The photographic plate presents a definite and permanent record beside which visual observations lose most of their significance. Perhaps the one field left for the older method is the measurement of sharp nuclei deeply enshrouded in nebulosity. New nebulae are now but rarely seen in the sky, although an hour's exposure made at random with a large reflector has more than an even chance of adding several small faint objects to the rapidly growing list of those already known. About 17,000 have already been catalogued, and the estimates of those within reach of existing instruments, based on the ratio of those previously known to those new in various fields, lie around 150,000.

Extremely little is known of the nature of nebulae, and no significant classification has yet been suggested; not even a precise definition has been formulated. The essential features are that they are situated outside our solar system, that they present sensible surfaces, and that they should be unresolved into separate stars. Even then an exception must be granted for possible gaseous nebulae which appear stellar in the telescope, but whose true nature is revealed by the spectroscope. It may well be that they differ in kind and do not form a unidirectional sequence of evolution. Some at least of the great diffuse nebulosities, connected as they are with even naked-eye stars, lie within our stellar system; while others, the great spirals, with their enormous radial velocities and insensible proper motions, apparently lie outside our system. The planetaries, gaseous but well defined, are probably within our sidereal system, but at vast distances from the earth.

In addition to these classes are the numberless small, faint nebulae, vague markings on the photographic plate, whose very forms are indistinct. They may give gaseous spectra, or continuous; they may be planetaries or spirals, or they may belong to a different class entirely. They may even be clusters and not nebulae at all. These questions await their answers for instruments more powerful than those we now possess.

Our present hope is to study them statistically, but until motions, either radial or transverse, have been detected we must content ourselves with the problem of their distribution. The first step is to make a systematic survey with powerful telescopes. Fath made a beginning by photographing each of the Kapteyn fields within reach of the Mount Wilson 60-inch reflector with uniform exposures of one hour. He discovered more than eight hundred new nebulae, and confirmed the fact that the small nebulae avoid the Milky Way. This last is vital in its bearing on the question of whether or not these objects belong to our system. A survey with long exposures suggests itself, analogous to that of Kapteyn, but based on the Milky Way rather than on the equator. The writer attempted such a program with the Yerkes 24-inch reflector, giving two-hour exposures. Little progress was made, but one fact stood out, namely, that in the fields of galactic latitude $-60°$ nebulae were very scarce when compared to the numbers met with in galactic latitude $+60°$.

The tendency of small nebulae to gather in clusters has been known for some time. Stratonoff's map of the distribution of faint nebulae in the Northern Hemisphere shows it very plainly. Max Wolf's more detailed study of the ecliptic regions with the 16-inch Bruce camera and the 30-inch reflector demonstrates that within these larger regions of the sky where nebulae tend to congregate there are points of accumulation about which the clustering is more marked. He measured the positions of more than four

[1] A dissertation submitted to the Faculty of the Ogden Graduate School of Science of the University of Chicago in candidacy for the degree of Doctor of Philosophy.

thousand new nebulae, and devised a classification which, while admittedly formal, offers an excellent scheme for temporary filing until a significant system shall be constructed.

The present paper has to do with certain clusters of small, faint nebulae which the writer found during the years 1914 to 1916 while photographing with the 24-inch reflector of the Yerkes Observatory. From about 1000 uncatalogued objects, 512 in 7 well-defined clusters were chosen for measurement. Known nebulae in the clusters numbered 76; hence there were, in all, some 588 objects, or an average of 84 per cluster. The fields are as given in Table I.

The problem of measuring and reducing accurate positions of objects at a considerable distance from the center of plates taken with a reflector of so large a focal ratio, 1:4, presented serious difficulties. The area covered by each plate is a square of some 110′ to the side. With the full aperture the stellar images are sensibly round only within 5′ of the optical center of the plate. From there outward the coma becomes more and more prominent, distorting the images first into an oval, and finally, near the edge of the plate, into the shape of an arrow, while the point about which the images build up becomes more and more eccentric. For images of various sizes this point will be at various distances from the centers of figure, and at 40′ from the center will fall very nearly at the point of the arrow. This introduces at once an overwhelming magnitude-error, masking whatever distortion of the field may exist.

TABLE I

FIELD	CENTER (1875.0)		NUMBER		
	α	δ	Known	New	Total
I	$1^h\ 0^m 30^s$	+31° 44′	21	57	78
II	1 42 20	32 0	3	81	84
III	11 3 54	29 27	8	178	186
IV	13 37 10	56 21	21	52	73
V	14 57 10	23 47	3	49	52
VI	17 11 22	43 50	5	43	48
VII	23 14 16	7 27	15	52	67
Total			76	512	588

If very faint stellar images could be used for reference, this error could be largely reduced. It was necessary, however, to use stars from the catalogues of the Astronomische Gesellschaft for reference, and with the long exposures required for the faint nebulae the images of these stars were very large. At the edge of the plate, for instance, the arrow-shaped image of a star of the ninth magnitude would often be fully a minute of arc in length.

It seemed inadvisable to make an exhaustive study of this magnitude-error, whence the alternatives were to use a restricted portion of the field or to sacrifice accuracy in the reduced positions. The second of these evils was chosen. The positions of the optical centers of images at various distances from the center of the field were determined empirically. Pairs of plates of a region were taken with apertures of 9 inches and with the full 24 inches and were compared in the Zeiss "blink" comparator. With the smaller aperture, and hence the smaller focal ratio, the images near the edge of the plates were sensibly round and small. Superimposed on the 24-inch images, they indicated where the wires should be set in measuring the larger distorted images. Trials were then made, measuring positions of A.G. stars all over the 24-inch plates, until a kind of technique was acquired. Judged by the aims in view and the results obtained, this empirical scheme fully justified itself.

At least two plates of each field were taken. In any case the two best plates were put on the "blink" comparator, and only those objects clearly nebulous on both plates were marked. The better plate was then placed on a Gaertner measuring machine. The nebulae and all the A.G. stars fainter than the seventh magnitude were measured in X and Y with the same screw. After an interval of a day or two the plate

was remeasured. Settings were read to 0.01 mm, corresponding to about 0."87 on the scale of the plate. The two measures of a nebula differed but seldom in this unit, and if faint reference stars could have been used, a higher degree of accuracy could have been maintained throughout the work.

In order to orient the plate, two stars were selected with as large a difference in right ascension and as small a difference in declination as possible. The difference in X was then computed in millimeters, assuming a scale-value of 87."4 per mm. The plate was placed in the measuring machine with the meridian roughly perpendicular to the screw, and adjusted with the tangent slow-motion until the setting on the two stars gave the computed difference to the limit of accuracy of the settings. This method reduced the constant of orientation of the plate to an almost negligible quantity.

Turner's method (*The Observatory*, 16, 373, 1893) was used as the basis for reducing the measures. The six plate-constants for each field were determined from the five or six A.G. stars most symmetrically distributed about the optical center, and graphs were constructed from which the values of $Y-Y_0$ and $X-X_0$ were corrected. The $\Delta\alpha$ and $\Delta\delta$ were then added directly to the α_0 and δ_0 of the assumed center, and final corrections to the positions were read from graphs constructed from Turner's formulae. Any A.G. stars not included in the determination of plate-constants furnished checks.

Since the distribution of the stars was about the same as that of the nebulae, it was hoped that the reduced positions of the latter would be of the same order of accuracy as those of the stars. For the 62 A.G. stars on the seven plates measured, the average difference from the A.G. positions was 1."0 in either co-ordinate. The settings on the nebulae could be made with greater precision than on the stars, hence these results justify placing the accuracy of the nebular positions at about 2."0 in either co-ordinate, except for such as were near the edge of the plates.

The positions are given for the epoch of the A.G. catalogues, 1875.0. Two of the N.G.C. nebulae had been measured by Lorenz from photographs made at Heidelberg. A comparison of his measures with the present measures shows the same second of arc in declination and the same tenth of a second of time in right ascension. The agreement is perfect to the last units used in the present paper, but as the nebulae, N.G.C. 7619 and 7626, are situated near the center of the plate, they cannot serve as a test of the accuracy of those near the edge. In several cases comparisons could be made with positions from visual measures, as given in the *Strassburg Annals*, Vols. III and IV. Here the agreement is not so good.

In one case, on the same night, positions of four objects were measured with reference to a certain star, which was, in turn, tied up to an A.G. star some distance away. The objects are given as N.G.C. 3550, 3552, 3554, and a nova which is designated as K_{12}. The photograph shows N.G.C. 3550 and 3554 properly placed with reference to the star, both in distance and in position-angle; there is nothing at all in the place given for N.G.C. 3552; K_{12} is properly placed from the star, but is in the N.G.C. position for No. 3552. The position of the reference star is given as about 17″ too small in declination. K_{12} is clearly N.G.C. 3552, and evidently the fourth object does not exist in the published position. As these objects were all in the same field of view in the telescope, one is at a loss to account for the discrepancy. A list of the comparisons is given in Table II.

The descriptions indicate form, brightness, and size, and occasionally the location of a neighboring star. Wolf's classification was used. It is, as he remarks, wholly empirical and probably without physical significance, yet it offers the best available system of filing away data, and will later be of great service when a significant order is established. One class was interpolated between g and h, and was designated g_0. Brightness was estimated in the order B, pB, pF, F, vF, eF, eeF, and eeeF. The range is from Herschel's Class II down to the limit of the plates. For several of the fields diameters were estimated to the nearest 5″. Otherwise the size was given in the order L, pL, pS, cS, S, vS, eS.

The classification given in Table III is illustrated in Plate III, copied from Wolf's engraving in Band III, No. 5, of the *Publicationen des Astrophysikalischen Instituts Königstuhl-Heidelberg*. The most striking feature is the great predominance of the classes e and f. These two classes form a continuous sequence from the brightest in the list to the very limits of the plates, where they are but mere fain

markings on the films. Eleven are clearly spirals, and the spindles are unexpectedly common. These results are typical.

The frequency of the classes e and f may merely be a way of stating that the scale of the telescope is too small to show the ordinary structure, but it must be remembered that many members of these classes are pretty large and bright and that the gradation in the series is apparently continuous. As far as telescopes of moderate focal length are concerned, the predominant form of nebulae as we know them at present is not the spiral, but is this same "e, f" class, described as round or nearly so, brightening more or less gradually toward the center, and devoid of detail. The brightest of the class are probably Messier 60 and N.G.C. 3379. Their spectrum, as derived from objective-prism plates, is continuous, and is probably of the same type as those of the spirals and the globular clusters. A detailed study on an adequate scale of the brighter members of the class will throw considerable light on the problem of the small nebulae.

TABLE II

HUBBLE *minus* STRASSBURG			HUBBLE *minus* STRASSBURG		
N.G.C.	$\Delta\alpha$	$\Delta\delta$	N.G.C.	$\Delta\alpha$	$\Delta\delta$
379	$0^s.0$	+ 3″	6329	$-0^s.3$	+3″
380	+0.1	+ 3	6332	−0.3	+6
382	+0.2	+ 1	6336	+0.1	+8
383	+0.1	0	7586	+0.2	+1
384	+0.1	+ 1	7608	−0 3	+6
385	+0.1	+ 2	7611	−0.2	−1
386	−0.2	− 2	7612†	0.0	+2
387	+0.2	+ 3	7617	+0.1	+1
3550*	+0.5	+24	7619†	+0.1	−1
3552	+0.1	+19	7623†	0.0	+1
3554	−0.2	+15	7626†	−0.2	−2
3558	−0.3	− 1			

* Nucleus is eccentric and undefined on the photograph, hence the photographic position is probably in error by several seconds of arc.

† Mean of the positions given in Vols. III and IV. N.G.C. 7621 is $5^s.4$ preceding, and 1′ 49″ south of 7623. There is a double star in the position published in the *Strassburg Annals*.

TABLE III

DISTRIBUTION OF VARIETIES OR CLASSES OF NEBULAE IN THE SEVEN CLUSTERS OR FIELDS

CLASS	FIELD							
	I	II	III	IV	V	VI	VII	Total
a	....	....	1	....	....	....	....	1
c	....	1	....	....	1	....	1	3
d	....	1	33	1	....	....	6	41
e	27	39	109	41	27	21	20	284
f	33	35	17	19	8	12	21	145
g	7	3	4	....	12	5	7	38
g_0	5	....	8	....	....	3	1	17
h	2	2	2	10	1	1	4	22
h_0	3	2	4	....	1	2	2	14
i	....	....	....	....	....	1	2	3
k	1	....	2	....	....	....	....	3
n	....	....	....	....	....	....	1	1
q	....	1	....	....	....	....	2	3
r	....	....	....	....	....	2	....	2
v	....	....	....	....	....	1	....	1
w	....	1	4	....	2	....	....	7
irreg	....	....	1	2	....	....	....	3

Messier 60 has a spiral as a very near neighbor—H III 44. The contrast in the two classes is well shown; so also in the case of N.G.C. 3379 mentioned above. Here there is a group of three fairly bright

nebulae: N.G.C. 3379, a globular nebula of class e; 3389, an open spiral; and 3384, which might be called a spindle, except that the wings flare out from the nucleus.

The three irregular forms are N.G.C. nebulae and are commented upon in the descriptions accompanying the positions.

Very little can be said concerning the surface-brightness of these objects. It is independent of the distance so long as the angular diameter is sensibly greater than that of a faint star. The photographic plate therefore records the absolute surface-brightness of the nebulae. High luminosity is a comparatively rare attribute and there is some relation between luminosity and absolute size; that is to say, the brighter usually have the greater angular diameter. Since it is hard to conceive of a relation between distance and absolute brightness, the fact that the faint nebulae are usually the smaller can be interpreted only in the light of a relation between luminosity and absolute size.

The clustering of the nebulae here recorded is very pronounced. In the center of Field III there are some 75 nebulae scattered over an area equal to that subtended by the full moon.[1] In order to examine the distribution of the different sizes, diameters were plotted against frequencies. The small scale of the

TABLE IV

DISTRIBUTION ACCORDING TO SIZE OF THE NEBULAE IN THREE FIELDS

DIAMETER	FIELD			WOLF'S FIELD IN PERSEUS
	I	III	VII	
5″	....	....	....	3
10	7	38	5	34
15	27	67	12	52
20	25	42	18	26
25	6	19	10	6
30	5	9	4	2
35	3	2	4	1
40	4	5	4	2
45	1	3	3	....
50	1	....	3	....
60	....	....	3	....
90	....	....	1	....

plates renders the number of smallest diameters very uncertain. Nebulae less than 10″ in diameter might easily be mistaken for stars and overlooked, especially if they are at some distance from the center of the field. The curves resemble probability-curves, as one would expect for random distribution in a cluster at a definite distance.

Exposures of two hours gave all of the nebulae recorded. Five-hour exposures brightened the images somewhat, but revealed no new ones. The conclusion would seem to be that the limits of the clusters had been reached. This, however, is uncertain, for the longer exposures gave relatively few stars which were not on the plates of shorter exposures. As a matter of fact, the 24-inch reflector at this altitude seems to have a maximum working efficiency at slightly over two hours. Save for very exceptionally clear and steady skies, the longer exposures add much labor for negligibly greater results. The diameters of the

[1] See Plate IV, enlarged from negative R 3352, taken with 120^{m} exposure on February 26, 1916. The numbers were marked on only those nebulae which promised to be readily visible on the engraving, and which were separated enough to give room for inscribing the number. The B.D. stars are designated by letters, for which the key is as follows.

FIELD III

STAR B.D.	STAR B.D.
A = +30°2107	J = +29°2125
B = +30°2108	K = +29°2126
C = +30°2109	L = +29°2128
D = +30°2110	M = +29°2129
E = +30°2115	N = +29°2130
F = +30°2121	P = +29°2133
G = +30°2123	R = +29°1970
H = +29°2123	S = +28°1971

faintest stars near the center of the field, with the full aperture, fine sky, and an hour's exposure, which are of about magnitude 17.5, are about 2″.0. Longer exposures are apparently subject to change of focus, differential refraction, and other disturbances which tend to increase the size of the images unduly, and hence to spread the total light over a larger area. The result is that the value of p in the reciprocity equation $It^p = iT^p$ does not remain constant throughout the exposure, but varies, beyond a certain value of

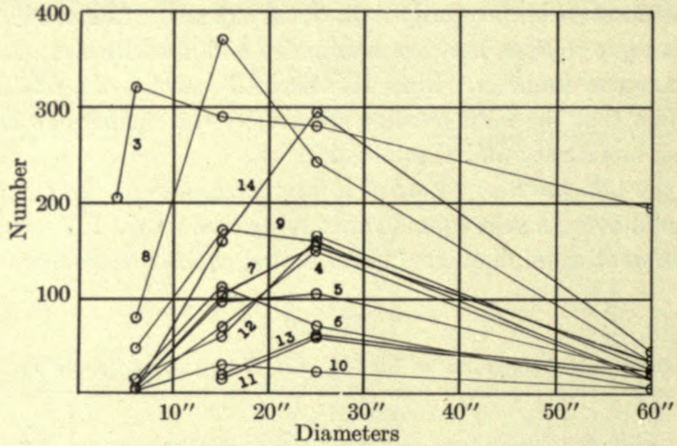


FIG. 1.—Distribution of size in Wolf's Nebel Listen Nos. 3 to 14

T, depending on the adjustments of the telescope, the position of the field, and the condition of the sky. However, the effect should be more noticeable on the stars than on nebulae which present surfaces.

I have plotted Wolf's lists of nebulae, Nos. 3–14, in the same manner, converting estimates of size into seconds of arc according to his table. These lists were made from plates taken with the 16-inch (41 cm) Bruce camera, of focal length 203 cm, of the Heidelberg Observatory. The curves (Fig. 1) take the

TABLE V

WOLF'S NEBEL LISTEN NOS. 3–14

List	Diameter						
	4″	6″	15″	25″	60″	200″	<200″
3	205	322	291	280	195	36	6
4	....	1	69	153	19	6	1
5	....	6	99	106	23	1	3
6	....	14	114	72	2	2	1
7	....	9	103	156	35	4	12
8	....	80	372	243	34	3	....
9	....	48	174	160	19	....	....
10	....	3	31	26	2	....	....
11	....	....	13	60	19	1	....
12	....	14	61	162	27	10	....
13	....	....	20	61	26	3	....
14	....	3	160	296	43	1	1

same form, save that for most the maximum frequency is for diameters between 20″ and 25″. One of his lists was made from plates taken with the 30-inch reflector at Königstuhl. It is of a field in Perseus, $\alpha = 3^h 12^m$, $\delta = +41° 6'$. Diameters of the 124 Wolf nebulae and five others were measured from plates taken with the Yerkes 24-inch reflector. This plot (Fig. 2) gives a maximum for diameters around 15″, and the longer focus of Wolf's 30-inch apparently does not add to the number of small nebulae distinguishable on the plates made with the shorter telescope.

The evidence, while far from conclusive, appears to indicate the existence of actual clusters of these small nebulae in the sky. If this is true, it is natural to suppose them physically connected, as is the case in star-clusters. It is not possible to form a conception of this state of affairs until some idea of their distance is acquired. Suppose them to be extra-sidereal and perhaps we see clusters of galaxies; suppose them within our system, their nature becomes a mystery.

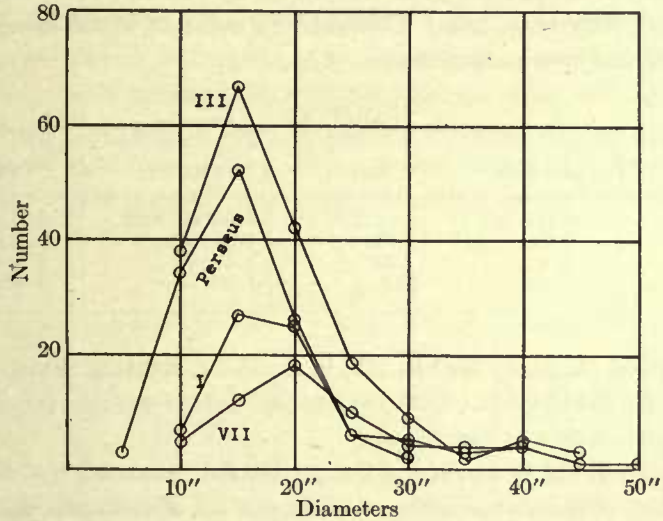


FIG. 2.—Distribution of size of nebulae in Wolf's Perseus and three Yerkes fields

The question of nebular distances is of first importance, for it is in terms of this quantity that the various dimensions may be expressed. The dark nebulosities, by their very nature, and the great diffuse clouds, some obviously connected with even naked-eye stars, may safely be considered as galactic, and this view is in accord with their low radial velocities with reference to our system.

The planetaries have repeatedly been measured for proper motion, with negligible results. Taking a value of 40 km/sec. for the average radial velocity, and an assumed lower limit of 0″.02 for the average annual proper motion, a tentative lower limit for the average distance of the largest, and hence probably the nearest, is found to be about 2000 light-years. There is thus no reason on this ground for placing them outside our system, especially in view of their decidedly systematic galactic distribution.

Rotation of these nebulae, as detected by the spectroscope, furnishes a means of relating mass and average density with distance. Assume an axis perpendicular to the line of sight, the mass as concentrated in the nucleus and the individual distant particles as rotating in equilibrium; let a be the radius, P the period of rotation, M the mass, and suppose the rotation to be circular. Then $a^3/P^2M=C$, a constant. Let the unit of distance be the light-year (LY); of time, the year; of mass, that of the sun (S), then C, as computed from the earth-sun system, is about 4×10^{-15}.

Let

α = the angular radius in seconds of arc
d = the distance in light-years
ρ = the density in terms of earth's atmosphere at sea-level
v = the linear velocity of rotation in km/sec.

Then the following relations hold:

$$(1)\quad M=3.4\times10^{-4}\,d\alpha v^2$$

$$(2)\quad \rho=1.4\times10^{-6}\left(\frac{v}{d\alpha}\right)^2$$

$$(3)\quad P=9.15\,\frac{d\alpha}{v}$$

The velocity of escape for the nebula is proportional to a/ρ and hence to v. This follows from the assumption that the particles are rotating in equilibrium, and therefore the factor of proportionality is the ratio between parabolic and circular velocity, that is, 1.4, and is independent of the distance. The value of v for those nebulae so far observed is small, ranging from 5 to 10 km. Hence, if the assumptions held only approximately, the velocity of escape would be small and of the same order as that for the earth. Since these nebulae are composed of the lightest gases, it follows that at any save very low temperatures the molecules would escape at a very rapid rate. Certainly the nebulae would dissipate if the temperatures were of the order of that of our own atmosphere.

TABLE VI

d	Diameter	Mass	Period	Density
10 LY	0.001 LY	1.2 S	1.5×10^{2} year	$1.8\times10^{-7}\rho$
10^{2}	0.01	12.	1.5×10^{3}	1.8×10^{-9}
10^{3}	0.1	120.	1.5×10^{4}	1.8×10^{-11}
10^{4}	1.0	1200.	1.5×10^{5}	1.8×10^{-13}

For an assumed typical planetary nebula, 20″ in diameter, rotating with a velocity of 6 km at 10″ from the perpendicular axis, Table VI has been constructed from formulae (1)–(3), expressing the order of magnitude of dimensions in terms of distance.

The velocity of escape would be about 8.4 km per second, whatever the distance.

Spectroscopic rotation of spirals furnishes an analogous set of formulae, and here the inclination of the axis may be roughly determined from the ratio of the two diameters of the nebulae. Let β be the semi-minor axis, then the formulae will be:

$$(4)\quad M=3.4\times10^{-4}\,dav^{2}$$

$$(5)\quad \rho=1.4\times\frac{a}{\beta}\times10^{12}\left(\frac{v}{da}\right)^{2}\text{ in suns per cu. LY, or}$$

$$=2.8\times\frac{a}{\beta}\times10^{-6}\left(\frac{v}{da}\right)^{2}\text{ in atmospheres}$$

$$(6)\quad P=\frac{9.15\,da}{v}.$$

The spirals form a continuous series from the great nebula of Andromeda to the limit of resolution, the smaller ones being much the more numerous. Considering them to be scattered at random as regards distance and size, some conception may be formed of their dimensions from the data at hand. The average radial velocity of those so far observed is about 400 km, while the proper motion is negligible. Putting the annual proper motion at 0.″05, the lower limit of the average distance is found to be about 7500 light-years. If they are within our sidereal system, then, as they are most numerous in the direction of its minor axis, the dimensions of our system must be much greater than is commonly supposed.

The observations point to very large values for the rotational components of velocity, although the necessarily small scale of the instruments employed in their study renders the measuring difficult. Pease has determined the velocity of rotation for N.G.C. 4594 with some degree of accuracy. At 120″ from the nucleus it amounts to 300 km and varies linearly with the distance outward. V. M. Slipher reports that for the Andromeda nebula the angular rotation is fastest near the nucleus, and that this type of rotation promises to be the more common.

Assume a typical spiral 400″ in diameter, with the ratio of the axes of figure as $\beta/a=0.1$, and with rotation perpendicular to the line of sight at a velocity of, say, 200 km at the periphery. These figures are apparently not very different from the average of the two dozen brighter spirals. Table VII gives the dimensions in terms of distance.

The velocity of escape is 280 km/sec.

At the lower limit of average distance of spirals the typical nebulae would be fifteen light-years in diameter, forty-five million times as massive as our sun, and 3×10^{13} as dense as our atmosphere. On the other hand, if the typical spiral nebula is placed at a suitable distance, its dimensions assume the same order of magnitude as those of our own stellar system.

The conception of our galaxy set forth by Eddington in his book *Stellar Movements and the Structure of the Universe* is that the Milky Way forms a ring around a central, slightly flattened cluster. This ring is supposed to rotate in equilibrium so that the stars may remain concentrated in the configurations they now form. Assuming the ratio of the two radii as one to five, and using Eddington's figures of 2000 parsecs for the distance of the Milky Way, and 10^9 suns as the mass of the inner cluster, the period and density may be computed and compared with those of the typical nebula placed at a distance such as will make the diameter the same as that of our system. The results are are given in Table VIII.

TABLE VII

d	a	Mass	Period	Density
10^2	10^{-1}	2.7×10^5	9×10^2	1.4×10^9 suns per cu. LY
10^3	10^0	2.7×10^6	9×10^3	1.4×10^7
10^4	10^1	2.7×10^7	9×10^4	1.4×10^5
10^5	10^2	2.7×10^8	9×10^5	1.4×10^3
10^6	10^3	2.7×10^9	9×10^6	1.4×10^1

TABLE VIII

	Distance	Radius	Mass	Period	Density
Nebula......	6×10^6 LY	6×10^3 LY	1.6×10^{10} S	5.4×10^7 year	5.6×10^{-1}
Galaxy......	....	6×10^3	10^9	2.5×10^8	1.2×10^{-2}

The velocities of escape would be about 280 km for the nebula and 170 km for the galaxy. Considering the problematic nature of the data, the agreement is such as to lend some color to the hypothesis that the spirals are stellar systems at distances to be measured often in millions of light-years. The computations by O. H. Truman[1] and by R. K. Young and W. E. Harper[2] of the motion of our system with respect to the spirals, based on the radial velocities of the spirals, are another and stronger argument for the hypothesis.

The principal objection lies in their apparently systematic distribution with respect to the Milky Way. The matter is usually stated in the form that "spirals avoid the Milky Way." There are less than 300 nebulae *known* to be spiral in form. The greatest of them all is just on the border. It is suggested that the spirals seem to follow the distribution of the small faint nebulae. If this is true, the most that can be definitely stated is that they tend to cluster in certain regions of the sky, in one of which the north pole of the galaxy is located.

As the small nebulae and the spirals inhabit the same regions of the sky, it is probable that the order of distance of the two classes is the same. Classes e, f, may even turn out to be spirals themselves. This, however, is a question for large instruments, and is outside the scope of the present paper.

[1] *Popular Astronomy*, **24**, 111, 1916.

[2] *Journal of the R.A.S., Canada*, **10**, 134, 1916.

TABLE IX

FIELD I OF NEBULAE

No.	(1875.0) α	(1875.0) δ	Class	Description	No.	(1875.0) α	(1875.0) δ	Class	Description
1..	$0^{h}56^{m}35^{s}.1$	+31°36′39″	f	pF, R, 20″d, *14m 20″p.	30..	$1^{h}\ 0^{m}33^{s}.3$	+31°54′41″	e	eF, E, eS.
2..	39.3	31 38 24	e	F, R, 20″d, *12m 20″n.	31..	39.3	31 25 23	h	F, mE130°, 1′l.
3..	49.0	31 22 14	h_0	F, mE110°, 60″l.	32..	43.2	32 17 18	e	vF, R, 40″d, *14m30″s.
4..	0 57 5.7	32 4 12	e	eF, st. *13m 30″np.	33..	59.1	31 35 14	g	eF, eS, st.
5..	54.5	32 17 41	e	vF, R, 25″d, *14m 30″sf.	34..	1 1 3.5	32 38 9	e	vF, cE40°*11m1′nf.
6..	0 58 8.9	32 8 33	e	vF, R, 25″d, *9 1′nf.	35..	11.3	31 13 16	h_0	vF, 310°, 1′l.
7..	22.3	31 33 12	e	eF, st.	36..	19.6	31 47 9	f	F, S, E60°, *14m1′s.
8..	41.8	31 45 33	f	pF, R, S, Δ2 faint*, bM.	37..	24.5	31 25 17	f	F, st. *14m1′np.
9..	42.7	31 17 58	f	pF, st. 2*13, 14 1′.5p.	38..	27.8	31 52 56	f	eF, vS, *15m20″p.
10..	54.7	31 16 30	g	F, eE0°, 30″l.	39..	32.7	31 45 48	e	eF, st. in line with 2f*.
11..	58.0	31 43 5	g	F, cE130°, 30″l, bM.	40..	50.3	31 45 57	e	eF, iR, *14m1′s.
12..	59.7	32 5 33	e	vF, R, 30″d.	41..	58.8	31 25 54	e	pF, R, 25″d. no nuc.
13..	0 59 13.9	31 56 21	f	vF, st. *16m40″sf.	42..	1 2 5.5	31 34 21	e	vF, st. *10m20″s.
14..	28.2	31 31 43	f	vF, st. *15m 1′.5f.	43..	20.4	31 29 4	e	vF, R, 45″d. no nuc.
15..	51.6	32 33 48	g	vF, E140°, 45″l.	44..	22.3	31 18 42	f	F, st. and sev f*.
16..	58.2	32 1 58	f	vF, E60°, 20″l 3f*.	45..	26.4	32 3 22	e	vF, st. *11m20″s.
17..	58.8	31 41 27	f	eF, eS.	46..	32.0	32 6 19	e	eF, iR*14m30″sf.
18..	1 0 0.7	31 54 35	e	F, st.	47..	39.7	31 30 21	g	vF, cE80°, S.
19..	3.6	31 18 39	e	vF, st. d. nuc.	48..	48.5	31 47 5	f	F, st. *15m1′nf.
20..	6.4	31 29 19	e	vF, lE, 20″l.	49..	49.0	31 41 39	f	eF, vS, *15m30″f.
21..	8.2	31 42 16	e	vF, st.	50..	49.8	31 57 3	f	eF, st. *14m1′np.
22..	10.9	31 43 12	h	vF, E90°, 1′l.	51..	1 3 5.3	31 42 7	f	vF, st. 2*14m1′f.
23..	15.0	32 24 1	e	eF, eS, 2*10, 11m1′nf.	52..	8.0	32 14 51	e	eF, st.
24..	18.9	31 30 22	g	vF, cE, S, *15m40″s.	53..	26.4	31 43 18	f	vF, st. Δ2vF*.
25..	22.0	31 1 42	e	vF, st.	54..	37.6	31 30 51	f	eF, st. bet. 2*.
26..	22.1	32 22 51	e	eF, R, 30″d, *12m1′.5nf.	55..	57.6	31 55 41	f	eF, st. *12m15″p.
27..	22.9	31 31 29	f	FcE60°1′l, *16m40″np.	56..	1 4 16.4	32 2 9	f	vF, st. bet. 2*.
28..	25.0	31 45 17	f	eF, E, eS.	57..	1 5 1.6	31 48 22	e	eF, st. *12m1′s.
29..	1 0 29.0	31 54 48	h_0	Fv, mE160°, 40″l*13m1′s.					

NEBULAE PREVIOUSLY KNOWN IN FIELD I

N.G.C.	α	δ	Class	Description	N.G.C.	α	δ	Class	Description
370...	$0^{h}59^{m}51^{s}.6$	+31°44′55″	g	vF, S, cE20°* 14m30″s.	394..	$1^{h}\ 1^{m}31^{s}.6$	+32°28′50″	f	F, st.
374...	1 0 12.5	32 7 35	g_0	pB, mE10°bet. 2*13m.	397..	36.4	32 26 32	f	vF, st.
376...	14.3	31 40 43	f	vF.	398..	1 2 0.0	31 50 50	f	F, st.
379...	22.5	31 51 8	g_0	pB, cE 0°, 60″×30″.	399..	5.2	31 58 1	g_0	F, E50° 40″l.
380...	24.5	31 48 53	e	pB, R, 40″d.	403..	20.0	32 5 9	k	pB, mE90°, 60″×20″.
382...	30.9	31 44 8	f	pB, R, 20″d.					
383...	32.0	31 44 38	e	pB, R, 1′d, bM.	387..	1 0 40.1	31 43 23	f	vF, eS, st.
384...	32.2	31 37 26	g_0	pB, cE135°, 30″l.					
385...	34.3	31 39 4	f	pB, R, 40″d.	I.C.				
386...	38.3	31 41 35	f	pF, st.	1618..	0 59 3.4	31 44 31	g_0	pF, cE, 150° 25″l, bM.
388...	54.2	31 38 28	f	F, st.	1619..	1 0 28.6	32 23 57	f	pF, st. bet. 2*11, 12m.
392...	1 1 29.1	32 27 59	f	pF, R, 30″d bM, *11m1′ sp.					

N.G.C. 379 and 372 are probably the same object, with α of 370, and δ the mean the two N.G.C. positions. There is no other object in the immediate vicinity.

400, 401, 402 } Faint stars in these positions; no nebulae near.

390, Faint star, 16m. in this position. No trace of a nebula.

TABLE X

FIELD II OF NEBULAE

No.	(1875.0) α	(1875.0) δ	Class	Description	No.	(1875.0) α	(1875.0) δ	Class	Description
1....	$1^h39^m32^s.1$	+31° 52′ 58″	f	F, S.	42...	$1^h43^m12^s.0$	+31° 52′ 35″	f	eeF, eS.
2....	41.7	32 46 3	e	eF, pS.	43...	12.2	32 22 58	f	eF, S.
3....	43.4	32 4 25	d	eeF, S.	44...	13.1	31 51 39	h	eeF, S.
4....	46.7	31 29 2	f	vF, S.	45...	13.2	31 59 34	e	eeF, vS.
5....	50.4	32 7 35	c	eF, pS.	46...	13.4	32 2 32	e	eeF, eS.
6....	55.6	31 24 29	e	eF, eS.	47...	17.9	31 57 14	f	vF, vS.
7....	59.0	32 10 21	f	vF, vS.	48...	19.6	32 25 39	f	vF, vS.
8....	1 40 27.5	31 24 17	h_0	eeF, S.	49...	20.7	31 50 3	h	eceF, S.
9....	48.3	31 30 29	e	eeF, vS.	50...	22.6	32 36 9	e	eeF, vS.
10....	50.4	31 37 46	e	eeF, vS.	51...	22.6	31 49 17	e	eeF, S.
11....	1 41 5.6	31 44 9	e	eF, S.	52...	23.8	31 47 57	e	eeF, eS.
12....	8.9	31 55 48	e	vF, vS.	53...	29.5	31 52 29	f	vF, S.
13....	9.4	31 59 34	f	vF, pS.	54...	30.5	32 27 43	f	pF, pS.
14....	20.2	31 53 23	e	eF, vS.	55...	37.6	31 53 20	e	eF, eS.
15....	32.6	32 20 2	f	vF, S.	56...	39.0	31 56 43	f	eF, eS.
16....	37.1	31 55 40	e	eF, vS.	57...	39.2	32 28 21	f	vF, S.
17....	47.6	32 16 38	f	eF, vS.	58...	39.3	32 13 46	e	eeF, vS.
18....	51.5	31 55 50	e	eeF, S.	59...	39.9	31 53 5	e	eeF, eS.
19....	1 42 0.5	31 56 38	e	eeeF, S.	60...	43.4	31 53 22	e	eeF, eS.
20....	0.8	32 28 25	f	vF, S.	61...	46.8	31 52 18	f	eeF, eS.
21....	15.8	32 11 28	g	eF, 30″l.	62...	48.9	32 16 44	f	eF, vS.
22....	16.4	31 52 43	e	eeF, eS.	63...	56.4	32 18 51	f	eF, vS.
23....	21.1	31 55 41	e	eeF, eS.	64...	58.8	32 0 10	e	eeeF, vS.
24....	23.5	31 57 24	f	F, S.	65...	1 44 0.7	32 27 29	e	eeF, vS.
25....	31.5	32 0 9	g	vF, S.	66...	0.8	32 9 58	e	eeF, eS.
26....	37.8	32 42 19	e	eeF, S.	67...	1.9	32 0 17	f	vF, vS.
27....	41.4	32 34 24	e	eeF, S.	68...	4.0	32 29 4	e	eeeF, S.
28....	43.5	31 29 20	f	eeF, eS.	69...	8.4	32 24 6	e	eF, vS.
29....	44.4	32 10 20	g	pF, 30″l.	70...	11.3	32 24 47	f	F, pS.
30....	50.4	32 19 55	f	vF, S.	71...	14.9	32 12 48	e	eeF, vS.
31....	50.9	32 47 16	e	eF, S.	72...	20.7	32 25 54	f	vF, S.
32....	51.2	31 24 50	e	eeF, eS.	73...	24.6	32 4 37	f	eeF, eS.
33....	58.0	32 0 4	e	eeF, eS.	74...	24.6	32 9 38	f	eF, eS.
34....	1 43 2.7	32 52 33	f	eF, S.	75...	34.9	32 5 34	f	eeF, eS.
35....	5.3	31 51 52	e	eeeF, eS.	76...	43.5	32 27 34	e	eeF, pS.
36....	7.0	31 48 17	f	pF, S.	77...	47.5	31 33 13	f	eF, eS.
37....	7.5	32 32 4	w	eF, 40″d.	78...	52.7	32 24 24	e	eF, vS.
38....	7.7	31 56 36	f	vF, vS.	79...	56.0	32 14 24	e	eeeF, vS.
39....	8.6	31 54 15	e	eeF, eS.	80...	57.4	32 4 2	e	eeF, S.
40....	9.1	31 53 1	f	eF, eS.	81...	1 46 28.6	31 22 2	f	eeF, eS
41....	1 43 9.3	32 6 11	e	eeF, vS.					

NEBULAE PREVIOUSLY KNOWN IN FIELD II

I.C.				
1733..	$1^h43^m25^s.6$	+31° 56′ 40″	f	vF, eS.
1735..	35.5	31 55 32	c	vF nuc., iR eeF neb., 60″d.
	1 42 20.4	31 57 55	q	270″×30″. Found visually by Barnard. Not catalogued.

TABLE XI

FIELD III OF NEBULAE

No.	α (1875.0)	δ (1875.0)	Class	Description
1....	$10^h59^m59^s.4$	+29° 22′ 40″	e	eeF, 25″d.
2....	11 0 2.1	29 23 37	e	35″d.
3....	14.7	29 46 56	e	eF, 30″d.
4....	22.0	29 15 59	e	vF, 20″d.
5....	23.5	29 5 59	f	eF, 30″d.
6....	25.8	29 27 21	f	vF, 30″d.
7....	42.5	28 39 11	e	ef, 15″d.
8....	56.1	29 20 10	d	eeF, 30″d.
9....	11 1 1.0	28 51 3	e	eF, 20″d.
10....	5.2	29 10 31	e	eF, 25″d.
11....	19.5	29 22 46	e	eeF, 15″d.
12....	22.4	28 39 12	w	eF, 30″d, open spiral.
13....	23.9	29 12 21	e	vF, 25″d.
14....	24.8	29 19 4	h$_0$	eeF, E165°, 35″×10″
15....	27.3	29 32 18	d	eeF, 15″d.
16....	28.4	29 5 32	e	vF, 30″d.
17....	28.4	29 12 58	d	eF, 20″d.
18....	29.2	29 31 11	e	eF, 15″d.
19....	32.3	29 6 30	h$_0$	eeF, 3160°.
20....	36.6	29 17 52	d	eeF, 20″d, some structure.
21....	38.6	29 17 13	f	eF, 20″d.
22....	53.4	29 19 33	e	eF, E60°, 30″×15″.
23....	56.6	29 54 3	d	eF30″d.
24....	11 2 2.2	29 36 46	d	eeF, 15″d.
25....	5.7	29 50 3	w	eeF, 45″d, open spiral.
26....	17.2	28 57 27	e	eF, 20″d.
27....	24.0	28 45 9	g	eF, E160°, 40″×20″.
28....	30.3	29 33 6	e	eeF, 10″d.
29....	36.0	31 14 51	e	vF, 25″d.
30....	36.4	29 43 59	e	eeF, 10″d.
31....	37.9	29 24 6	d	eeF, 20″d.
32....	38.7	29 26 44	e	eeF, 15″d.
33....	38.8	29 44 12	e	eeF, 15″d.
34....	39.8	29 20 17	e	eeF, 15″d.
35....	40.3	29 54 55	e	eeF, 15″d.
36....	41.2	29 27 20	w	eeF, nuc. 10″d, ring, 30″d.
37....	41.4	28 55 57	e	eF, 15″d.
38....	42.8	29 23 45	d	vF, 15″d.
39....	44.9	29 23 51	e	eF, 10″d.
40....	47.3	29 18 17	k	vF, E150°, 45″×15″.
41....	48.0	29 43 23	g$_0$	eeF, E40°, 20″×10″.
42....	48.3	29 21 21	e	eF, 15″d.
43....	54.0	29 21 19	g$_0$	eF, 30″×10″.
44....	55.7	29 35 33	e	F, 20″d.
45....	56.6	28 55 41	e	eF, 35″d.
46....	58.2	29 13 50	g	eeF, E50°, 30″×10″.
47....	11 3 4.1	29 10 39	a	eeF, 15″d, structure.
48....	4.3	29 38 56	g$_0$	eeF, E80°, 20″×10″.
49....	21.6	29 1 14	d	eF, 15″d.
50....	22.6	29 18 15	d	eeF, 20″d.
51....	23.4	29 17 21	e	vF, 20″d.
52....	23.6	29 39 35	e	eF, 20″d.
53....	24.3	29 40 11	e	eeF, 20″d.
54....	27.9	29 9 3	f	eF, 15″d.
55....	28.6	30 7 9	f	eeF, 30″d.
56....	28.7	29 0 47	d	eeF, 15″d.
57....	30.1	28 49 9	e	eeF, 20″d.
58....	31.4	29 43 22	e	F, 15″d.
59....	31.5	29 28 6	e	eF, 15″d.
60....	32.5	29 14 55	e	eF, 15″d.
61....	33.4	28 57 49	e	eF, 15″d.
62....	35.8	29 18 9	f	vF, 20″d.
63....	38.5	29 23 55	e	eeF, 10″d.
64....	39.6	29 23 9	a?	eF, 35″×25″. E35°, a miniature Dumb-bell.
65....	39.7	29 25 39	e	eeeF, 10″d.
66....	11 3 40.1	29 25 48	e	eeeF, 10″d.

No.	α (1875.0)	δ (1875.0)	Class	Description
67..	$11^h\ 3^m40^s.3$	+29° 23′ 57″	e	eeF, 10″d.
68..	41.3	29 21 55	g$_0$	eF, E110°, 30″*10″.
69..	41.9	29 22 21	e	eF, 20″d.
70..	43.7	30 7 14	e	eeF, 20″d.
71..	44.7	29 22 38	e	eeF, 20″d.
72..	46.2	29 28 7	f	eF, 20″d.
73..	46.4	29 30 25	d	eF, 15″d.
74..	49.8	29 22 46	d	eeF, 20″d.
75..	51.6	29 22 53	e	eeF, 10″d.
76..	52.4	29 22 34	e	eeF, 15″d.
77..	52.9	29 43 59	e	eeF, 20″d.
78..	53.6	28 59 39	e	F, 35″d.
79..	54.5	29 26 1	d	eeF, 20″d.
80..	54.7	29 23 5	e	eeF, 20″d.
81..	55.1	29 21 50	e	eF, 15″d.
82..	56.7	29 26 22	e	eeF, 15″d, E50°.
83..	56.9	29 34 40	e	eF, 15″d.
84..	57.5	29 16 59	e	eF, double nebula, nuc. 4″ apart.
85..	57.6	29 8 7	e	eF, 30″d.
86..	57.7	29 27 19	h$_0$	eeF, E140°, 15″×5″.
87..	11 4 0.8	29 17 51	e	eeF, 10″d.
88..	1.0	28 56 28	e	eeF, 20″d.
89..	1.4	29 22 15	e	eF, 15″d.
90..	1.4	29 39 5	e	eeF, 15″d.
91..	1.8	28 57 21	e	vF, 30″d.
92..	3.4	29 27 26	e	eF, 10″d.
93..	3.7	29 29 10	e	eeF, 20″d.
94..	2.7	29 20 17	e	vF, 20″d.
95..	3.8	29 2 9	e	eeF, iR.
96..	4.4	29 27 33	e	eF, 10″d.
97..	5.7	29 28 23	e	eeF, 15″d, faint extensions.
98..	5.8	30 14 51	e	eF, st.
99..	6.9	29 22 50	e	eF, 15″d.
100..	7.6	28 56 51	h$_0$	eeF, E25°, 30″×10″.
101..	9.4	29 14 23	e	eeF, 15″d.
102..	9.9	29 29 29	d	eeF, 10″d.
103..	10.0	28 53 55	e?	eeF, faint extensions 60″×40″?
104..	10.1	30 0 27	d	eF, 30″d.
105..	10.6	29 8 48	g$_0$	eF, E145°, spiral, 40″×20″.
106..	12.8	29 28 58	h	eeeF, 20″×10″.
107..	13.4	29 23 15	e	eeF, 15″d.
108..	13.5	29 21 19	g$_0$	eeF, E125°, 25″×15″.
109..	13.8	29 47 14	d	eeF, 20″d.
110..	14.2	30 0 57	k	eF, E40°, 34″×20″.
111..	14.4	29 25 24	e	eF, 15″d.
112..	15.6	29 29 36	d	eeeF, 10″d.
113..	18.6	28 55 56	e	eeF, 15″d.
114..	20.2	28 53 6	f	eeF, 20″d.
115..	22.8	28 54 6	e	eeF, 20″d.
116..	27.9	29 23 25	f	eF, 35″d.
117..	27.9	29 26 40	e?	eeF, 60″×40″, spiral?
118..	28.4	29 22 31	e	eF, 45″d.
119..	28.6	29 21 58	d	eeF, 15″d.
120..	28.6	29 25 18	e	eeF, 10″d.
121..	30.2	29 37 42	e	eeF, 15″d.
122..	32.0	29 25 37	d	eeF, 15″d.
123..	34.4	29 21 33	e	eF, 20″d.
124..	34.9	29 42 1	e	eF, 20″d.
125..	35.5	29 12 10	e	eeF, 10″d.
126..	36.0	29 21 0	e	eF, E60°, 20″×15″.
127..	37.0	29 27 7	d	eeeF, 15″d.
128..	11 4 38.5	28 56 22	e	eF, st.

TABLE XI—*Continued*

No.	(1875.0) α	(1875.0) δ	Class	Description	No.	(1875.0) α	(1875.0) δ	Class	Description
129...	$11^h 4^m 39^s.4$	+29°24′33″	f	vF, 25″d.	154..	$11^h 5^m 35^s.5$	+29°15′ 0″	e	eeF, 30″d.
130...	40.2	29 12 57	e	eeF, 15″d.	155..	43.6	28 57 24	e	eF, 40″d.
131...	41.8	29 27 40	g	eeF, E95°, 20″×10″.	156..	49.2	28 42 34	f	eF, st.
132...	46.8	29 19 18	g_0	eeF, 30″×15″.	157..	51.3	28 43 12	e	eeF, 30″d.
133...	47.9	29 31 9	d	eeF, 10″d.	158..	59.6	28 57 38	e	eeF, 30″d.
134...	49.3	29 26 1	f	eF, 15″d.	159..	11 6 6.9	28 44 55	d	eeF, 30″d.
135...	49.9	29 29 19	e	eeF, 10″d.	160..	9.7	29 29 30	d	eeeF, 20″d.
136...	49.9	29 14 45	e	eeF, 15″d.	161..	10.6	28 40 46	e	eF, 30″d.
137...	50.5	29 25 27	e	eF, 30″d.	162..	11.8	29 4 8	f	vF, st.
138...	51.5	29 22 55	e	eF, 10″d.	163..	12.8	30 11 16	e	eeF, 10″d.
139...	52.7	29 23 21	e	eF, 10″d.	164..	17.5	29 25 47	e	eF, 15″d.
140...	54.1	29 29 57	e	eeF, 15″d.	165..	23.2	28 43 55	f	eeF, 20″d.
141...	11 5 3.0	28 56 43	e	vF, 30″d.	166..	24.9	28 39 40	e	eeF, 30″d.
142...	4.7	29 16 36	e	eF, 15″d.	167..	27.8	28 41 26	e	eeF, 30″d.
143...	6.8	29 15 53	e	eeF, 20″d.	168..	29.0	28 56 22	e	eeF, 20″d.
144...	7.6	28 53 4	d	eeF, 15″d.	169..	40.9	29 20 27	d	eeeF, 20″d.
145...	11.6	29 38 5	e	eeF, 20″d.	170..	37.7	28 33 23	d	eeeF, 15″d.
146...	12.3	29 10 1	d	eF, 20″d.	171..	42.7	29 37 59	e	eeF, 20″d.
147...	13.5	30 9 30	d	eF, 20″d.	172..	44.2	29 5 13	d	eeeF, 15″d.
148...	14.4	30 6 28	e	eF, 20″d.	173..	50.6	29 18 31	e	eeF, 20″d.
149...	14.7	29 20 38	w	eF, 25″d, spiral.	174..	11 7 11.1	28 32 54	d	eeF, 20″d.
150...	15.6	29 8 19	d	eeeF, 15″d.	175..	14.9	30 14 45	e	eF, 20″d.
151...	17.1	29 29 16	e	eF, 20″d.	176..	19.2	29 18 25	h	eeeF, 30″×10″.
152...	19.4	29 10 52	g	vF, E40°, 50″×20″.	177..	27.1	29 6 26	f	eF, 20″d.
153...	11 5 34.3	29 25 10	d	eeF, 30″d.	178..	11 7 32.9	28 51 30	e	eF, 30″d.

NEBULAE PREVIOUSLY KNOWN IN FIELD III

N.G.C.	α	δ	Class	Description	N.G.C.	α	δ	Class	Description
3527..	$11^h 0^m 31^s.4$	+29°12′ 6″	f	vF, 35″d.	3554.	$11^h 3^m 57^s.7$	29°22′15″	e	vF, 25″d.
3536..	11 2 5.3	29 9 5	e	F, 40″d.	3558.	11 4 10.9	29 13 17	f	vF, 15″d, with what appears to be a faint ring 50″ in d.
3539..	22.9	29 20 56	g_0	F, E5°, 60″×20″.					
3550..	11 3 53.5	29 26 47		pB, eccentric nuc., 35″×25″.	3561.	11 4 28.4	29 22 31	e	eF, 45″d.
3552..	11 3 52.2	29 24 38	e	F 20″d.					

TABLE XII

FIELD IV OF NEBULAE[1]

No.	(1875.0) α	(1875.0) δ	CLASS	DESCRIPTION	No.	(1875.0) α	(1875.0) δ	CLASS	DESCRIPTIO
1....	13h32m33s.0	+56° 18′ 28″	e	F, cS, *15m10″n.	36...	13h37m58s.2	+56° 9′ 31″	h	eeF, S.
2....	13 33 0.4	56 49 46	e	eeF, pS.	37...	13 38 4.3	56 7 32	f	eeF, S.
3....	16.0	55 49 23	e	eF, S.	38...	9.8	56 7 11	f	eeF, eS.
4....	41.7	57 9 1	e	eF, S.	39...	15.8	56 13 9	e	eeF, eS.
5....	55.6	56 5 4	e	vF, eS.	40...	17.1	56 13 57	f	eF, vS.
6....	56.9	56 6 15	e	eF, S.	41...	29.1	56 16 49	e	eF, S.
7....	13 34 9.1	55 50 46	e	eeF, eS.	42...	35.2	56 15 5	h	eF, vS.
8....	11.3	56 32 8	f	eF, eS.	43...	35.4	56 13 55	h	eeF, eS.
9....	25.9	56 29 14	f	eF, eS.	44...	37.3	56 14 41	f	eF, vS.
10....	56.6	56 42 36	e	eF, vS.	45...	47.3	56 41 19	e	eeF, cS.
11....	57.7	57 0 46	f	eF, vS.	46...	52.8	55 35 23	e	eeF, eS.
12....	13 35 4.9	56 45 21	h	eeF, S.	47...	56.4	56 12 58	f	eF, vS.
13....	49.8	56 13 38	h	vF, S.	48...	13 39 6.9	56 15 45	e	eeF, eS.
14....	52.0	56 52 58	e	eF, cS.	49...	7.9	56 16 31	h	eF, vS.
15....	53.1	56 3 25	e	eeF, eS.	50...	8.1	56 5 45	f	vF, S.
16....	13 36 20.1	55 50 25	e	eeF, eS.	51...	9.2	56 11 45	e	eeF, eS.
17....	29.1	56 51 25	e	eF, S.	52...	9.4	55 56 14	e	eeF, eS.
18....	33.1	55 49 59	e	eeF, eS.	53...	13.3	56 16 32	f	eeF, vS.
19....	33.2	56 43 54	f	eF, eS.	54...	17.6	56 10 33	e	eeF, eS.
20....	38.6	55 46 18	e	eeF, eS.	55...	19.8	56 10 50	e	eeF, eS.
21....	39.0	56 18 33	h	F, 30″l.	56...	23.0	56 11 40	e	eF, eS.
22....	41.0	56 12 2	d	eeF, S.	57...	25.1	56 16 43	e	eeF, eS.
23....	43.7	56 42 11	e	eeF, S, *15m10″s.	58...	30.3	56 26 49	f	eF, eS.
24....	46.2	56 48 12	e	eF, cL.	59...	31.6	56 20 3	e	eeF, S.
25....	49.7	56 41 26	f	eF, S.	60...	45.1	56 29 5	f	eF, vS.
26....	53.6	56 48 57	e	eeF, eS.	61...	45.7	56 34 46	e	eeF, S.
27....	55.7	56 27 19	h	eeF, S.	62...	54.2	56 15 18	e	eeF, eS.
28....	56.1	56 40 17	e	eeF, S.	63...	13 40 3.2	56 37 22	e	eeF, cS.
29....	13 37 7.2	56 4 29	f	vF, S.	64...	5.9	56 30 56	e	eeF, eS.
30....	11.6	55 46 36	e	eeF, eS.	65...	5.9	56 30 29	h	eeF, 30″l.
31....	19.0	56 24 54	e	eF, S.	66...	27.2	56 6 27	e	eeF, vS.
32....	20.2	56 26 51	f	eeF, vS.	67...	13 41 27.2	56 20 38	e	eF, 60″d.
33....	35.5	57 7 6	e	eF, cS.	68...	38.8	55 47 15	e	eF, eS.
34....	46.0	56 5 6	f	eeF, S.	69...	47.4	55 44 54	f	eF, vS.
35....	13 37 54.0	56 10 12	h	eeF, S.	70...	13 42 40.2	56 15 54	e	ee F, S.

NEBULAE PREVIOUSLY KNOWN IN FIELD IV

N.G.C.				
5278..	13h36m59s.45	+56° 18′ 3″.8		
5279..	37 3.72	56 18 14.5		
5294..	40 39.7	55 55 2	f	eF, S, *15m1′np.

N.G.C. 5278 and 5279 form a double nebula, somewhat similar to Messier 51. 5278 is the nucleus and 5279 is at the tail of the arm. The spiral apparently has but one branch.

[1] Field IV covers the position of a group of 18 small nebulae announced by E. E. Barnard in *Astronomische Nachrichten*, **125**, 369, 1890. The positions there given were rough estimations from the stars B.D. +56°.1679 and B.D. +56°.1682. On the photographs, the nebulae in this region are so small and so crowded that I have been able to identify only three individuals of the group. Barnard's Nos. 4, 7, and 18 are very probably my Nos. 41, 43, and 62.

TABLE XIII

FIELD V OF NEBULAE

No.	(1875.0) α	δ	Class	Description	No.	(1875.0) α	δ	Class	Description
1...	$14^h53^m52^s.5$	+23°10′16″	e	eF, S, R.	26...	$14^h57^m\ 6^s.1$	+24° 5′56″	f	F, bet. 2*14, 15m.
2...	54.5	23 57 39	e	vF, R, 20″d, *18m 40″nf.	27...	8.4	23 47 22	g	eF, cS, iR.
3...	14 54 56.2	23 53 37	g	eF, S, m3. *16m1′np.	28...	8.9	24 16 59	e	eF, S.
4...	58.1	23 16 56	e	vF, pS, iR.	29...	10.3	23 50 31	e	eF, S.
5...	14 55 6.7	23 24 32	f	eF, S.	30...	11.3	23 46 44	e	eF, S.
6...	16.2	24 5 30	f	F, S, *17m30″n.	31...	11.8	23 49 57	e	eF, S.
7...	31.4	24 6 9	w	F, 30″d. Spiral.	32...	13.6	23 53 2	h	eF, S.
8...	35.9	23 58 27	g	vF, mE, 40″l, bet. 2*.	33...	18.8	23 44 22	g	eF, S.
9...	37.3	24 12 53	e	eF, eS.	34...	24.1	23 42 42	e	eF, cS, iR.
10...	14 56 13.7	23 52 21	g	F, E, spiral?	35...	24.3	24 4 40	e	eF, S, iR.
11...	17.7	24 2 30	g	F, E180°.	36...	26.8	23 45 2	e	eF, vS, iR.
12...	26.3	24 0 51	h_0	vF, S, iR.	37...	35.9	24 6 37	e	eF, S.
13...	27.0	24 9 28	g	F, vS, E.	38...	41.7	24 35 7	f	eF, S.
14...	28.6	23 23 8	e	vF, S, R, 15″d, no nuc.	39...	43.0	23 24 38	e	vF, R, 30″d, no nuc.
15...	30.0	23 54 53	e	vF, vS, R.	40...	51.7	24 0 48	g	eF, vS, Δ with 2*14 and 16m.
16...	32.6	24 2 47	f	eF, vS.					
17...	46.4	24 3 54	e	eF, S, iR.	41...	14 58 0.6	23 18 4	e	vF, 25″d, spiral?
18...	47.8	24 36 4	e	vF, S, iR.	42...	6.8	23 11 21	g	F, eL, mE180°, 80″×15″.
19...	51.2	23 40 4	e	vF, vS.	43...	18.5	23 26 30	g	eF, S, 20″d.
20...	56.0	23 51 10	e	eF, vS, R.	44...	19.8	23 21 55	f	vF, R? 60″d.
21...	58.7	23 49 12	f	eF, vS, R.	45...	25.9	23 25 35	e	eF, S, R, 20″d.
22...	58.7	23 50 14	e	eF, eS, R.	46...	48.4	23 40 57	g	eF, cS, mE.
23...	59.0	23 51 41	g	eF, S, lE.	47...	54.7	23 54 12	e	F, mE 180°.
24...	14 57 4.3	23 51 51	e	eF, S.	48...	14 59 56.8	24 10 32	e	vF, S, iR, bM.
25...	14 57 4.3	23 52 8	f	eF, E.	49...	15 0 7.2	23 52 11	e	eF, S, iR.

NEBULAE PREVIOUSLY KNOWN IN FIELD V

N.G.C. 5829..	$14^h57^m\ 9^s.6$	+23°49′29″	w	open 2br, spiral.	I.C. 4526	$14^h57^m\ 5^s.9$	23°50′31″	e	pB, R, 18″d.
					4532	59 21.7	23 44 43	e	pB, S, E.

I.C. 4526 is connected with N.G.C. 5829. The two form a double nebula fashioned as a miniature of Messier 51.

TABLE XIV

FIELD VI OF NEBULAE

No.	(1875.0) α	(1875.0) δ	CLASS	DESCRIPTION
1....	$17^h\ 8^m16^s.7$	+44° 5′ 35″	f	vF, vS, *13m, 1′f.
2....	29.9	43 26 6	f	vF, vS, st.
3....	35.2	43 23 8	g	eF, E 60°, *13m40″sp.
4....	52.6	42 57 44	f	F, S, st.
5....	17 9 2.6	44 18 28	e	vF, vS, *16m, 40″s.
6....	14.2	44 16 11	e	eF, S, *16m, 40″f.
7....	17.5	43 50 51	f	vF, sharp nuc. 30″d.
8....	33.2	43 2 38	e	F, pS, *17m, 1′n.
9....	35.1	44 2 54	e	F, vS, *15m, 30″f.
10....	41.1	43 38 39	g_0	pF, S, mE, 60°*14m, 30″p.
11....	53.8	43 52 2	e	vF, vS, *17m, 40″n.
12....	17 10 3.4	44 12 35	f	eF, eS, *16m, 30″n.
13....	23.3	43 49 32	e	vF, vS, bet. 2 vf*.
14....	25.5	43 43 7	f	vF, vS.
15....	29.1	43 44 48	e	vF, vS.
16....	33.0	44 4 43	g	vF, S.
17....	37.7	44 5 32	e	eF, vS.
18....	39.0	43 42 38	g	vF, eS, *16m, 40″sf.
19....	40.2	44 5 20	h	eF, vS.
20....	46.7	43 51 14	f	vF, vS, *16m, 40″sf.
21....	52.8	43 33 9	f	vF, S, *16m, 40″sf.
22....	55.7	44 4 8	g	F, cE 70°, *14m, 40″n.
23....	17 11 16.3	43 10 57	f	vF, S.
24...	$17^h11^m25^s.9$	+43°25′48″	f	pF, S, *16m, 40″f.
25...	33.9	43 47 21	g	vF, vS, cE 160°, *15m, 40″np.
26...	36.7	43 42 51	h_0	vF, S, cE 120°, faint nuc.
27...	43.0	43 53 35	g_0	pF, S, cE 20°, *14m, 1′.5np.
28...	45.7	43 55 42	f	F, vS, *15m, 40″nf.
29...	48.6	43 58 50	e	vF, S, *13m, 1′.5n.
30...	57.1	44 8 50	e	eF, eS.
31...	57.8	44 8 6	e	eF, S.
32...	57.9	43 44 57	e	vF, vS, *15m, 30″f.
33...	17 12 13.3	44 2 16	e	F, eS, *12m, 1′n.
34...	26.2	44 12 21	e	F, eS.
35...	37.2	44 12 12	e	F, eS, Δ with 2*12m.
36...	38.4	43 28 52	f	pF, vS, *1′.5s.
37...	40.9	43 54 40	h_0	eF, cE 150°, no nuc.
38...	44.9	43 45 22	e	vF, vS, Δ with 2*16m.
39...	50.6	43 39 48	f	vF, eS, Δ with 2 f*.
40...	51.0	43 48 16	e	vF, vS, *16m, 40″nf.
41...	17 13 4.9	43 36 37	e	eF, vS, *15m, 20″s.
42...	27.2	43 40 39	e	vF, vS.
43...	17 13 39.2	43 44 19	e	vF, S.

NEBULAE PREVIOUSLY KNOWN IN FIELD VI

No.	α	δ	Class	Description
N.G.C. 6323..	$17^h\ 9^m30^s.6$	+43°55′42″	i	pF, mE, ns, 40″l.
6329..	17 10 27.3	43 49 40	f	pF, pL, slE.
6332..	17 11 15.2	43 48 5	g_0	pF, pL, E 45°.
6336..	17 12 30.0	43 55 35	v	pF, open spiral, 45″d.
I.C. 4645.	$17^h10^m53^s.0$	43°14′40″	e	vF, pS, Δ with 2 faint*.

N.G.C. 6327 is on the plate but was not measured.

TABLE XV

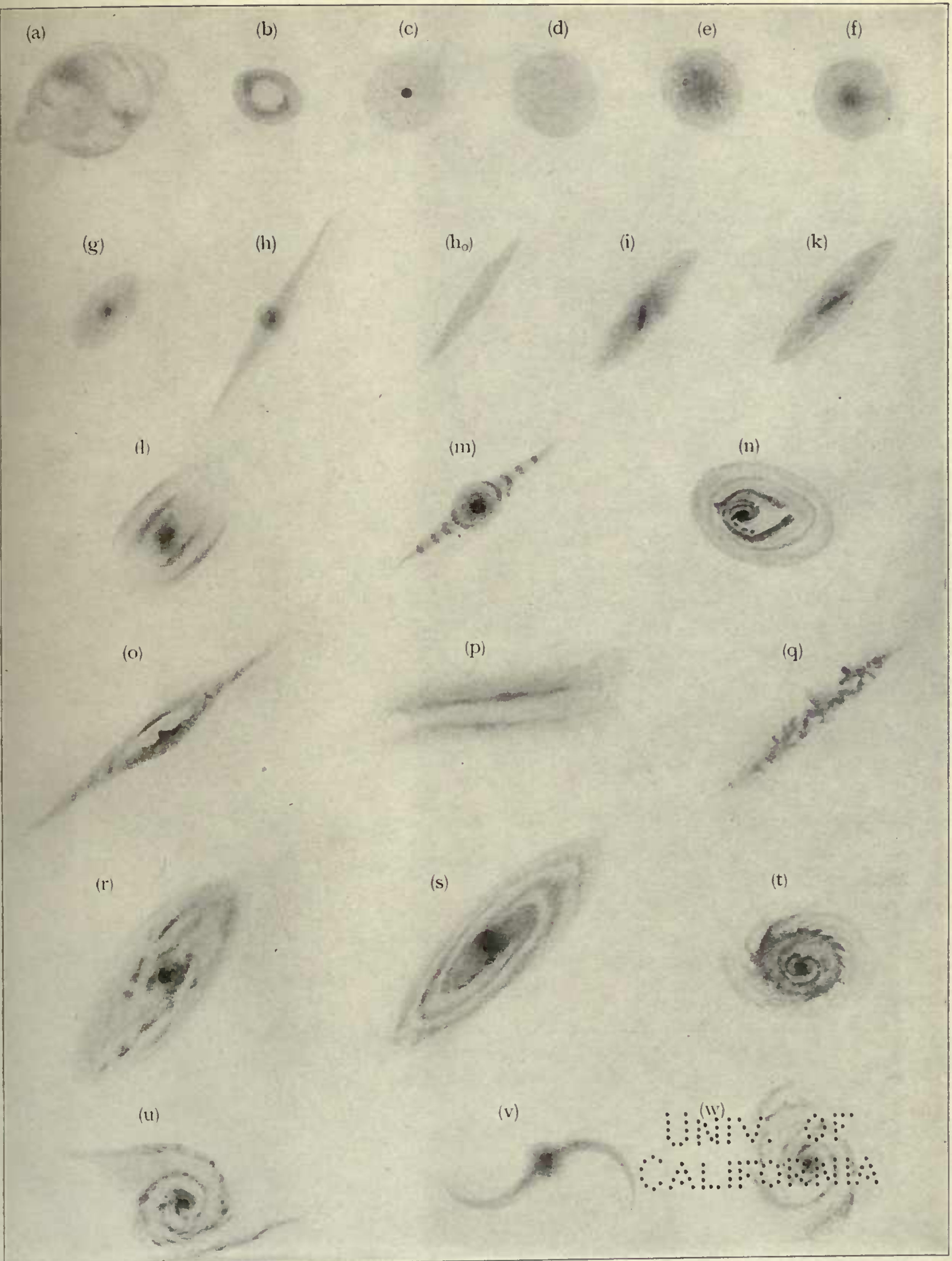
Field VII of Nebulae

No.	(1875.0) α	(1875.0) δ	Class	Description
1	23h10m25s.7	+8°13′28″	f	st. 14m.
2	23 11 19.4	7 34 13	e	F, S, *17m30″s.
3	39.3	7 45 26	d	vF, R, no nuc., 16m45″ np.
4	47.3	7 3 55	f	eF, S, R, no nuc.
5	23 12 23.1	7 18 20	c	vF, st. nuc. with ring 45″d.
6	42.2	6 45 7	d	eF, S, R, no nuc.
7	51.1	7 2 10	q	F, lbM, mE100°, 100,′×20″.
8	23 13 17.2	7 24 12	h_0	vF, S, lE50°*14m30″p.
9	19.4	7 34 51	q	F, sharp nuc., mE70°, 80″×20″.
10	29.9	7 31 15	f	F, S, E150°.
11	33.6	8 6 51	d	eF, pS, R.
12	35.4	7 52 39	g	pF, bM, mE150° 40″l.
13	41.6	7 32 2	g	eF, vS.
14	41.6	7 18 13	e	vF, vS, Δ2 faint *.
15	49.1	7 2 16	e	vF, S, Δ2 faint *.
16	52.7	7 14 52	h	F, sharp nuc. vmE20° 90″×15″.
17	56.6	7 19 16	e	eF, pL, no nuc.
18	23 14 2.4	6 51 8	f	F, S, R, *14m90″n.
19	2.9	7 38 55	f	F, S, R, bM.
20	18.4	7 42 40	f	F, S, bM.
21	24.4	7 45 35	e	eF, vS, *16m30″s.
22	31.3	7 27 10	e	eF, vS, bet. 2*.
23	34.9	7 31 47	e	vF, S.
24	36.0	7 30 3	f	vF, vS.
25	36.2	7 42 4	f	vF, vS.
26	23 14 37.5	7 41 4	f	vF, vS.
27	23h14m41.8	+7°29′40″	h	FN, mE160°, 80″×20″.
28	41.8	7 13 46	f	pF, vS, bM, Δ with 2 faint *.
29	42.4	7 44 32	e	eF, eS,*14m1′sp.
30	46.1	7 32 31	n	pFN, eccentric,mE90°.
31	46.2	7 29 21	i	pF, vS, R.
32	52.8	6 40 49	f	st. 14m.
33	54.9	7 32 39	e	F, S, lE.
34	56.2	7 10 7	i	vF, S, E, *14m30″sf.
35	56.9	6 47 41	e	vF, lE, *15m30″s.
36	58.5	7 33 24	e	vF, vS, *17m30″f.
37	23 15 5.9	7 51 23	e	vF,R,lvM,40″d,*12,1′n.
38	11.1	7 20 15	f	vF, S, E, *14m30″sp.
39	16.9	7 34 23	e	vF, vS, *15m1′np.
40	20.4	7 38 15	d	vF, vS.
41	21.8	8 18 24	h	vF, E, *9m, superimposed.
42	26.0	8 23 37	d	pF, pL, R, lbM.
43	28.7	7 29 43	f	F, S.
44	53.0	8 15 14	e	eF, pL, iR, no nuc.
45	56.3	7 46 32	e	eF, S, *16m40″p.
46	23 16 24.2	7 40 32	e	vF, E, *17m40″f.
47	38.8	8 18 39	h_0	eF, no nuc., vmE175°, 150″×30″.
48	42.5	7 33 39	g	vF, S, E.
49	43.4	7 36 39	e	eF, pS, no nuc. Trapz. of 4 *.
50	55.3	7 51 8	e	vF, S, *12m1′s.
51	23 17 14.2	7 37 37	e	eF, vS, *12m2′nf.
52	23 17 34.9	6 55 40	d	eF, pS, no nuc.

Nebulae Previously Known in Field VII

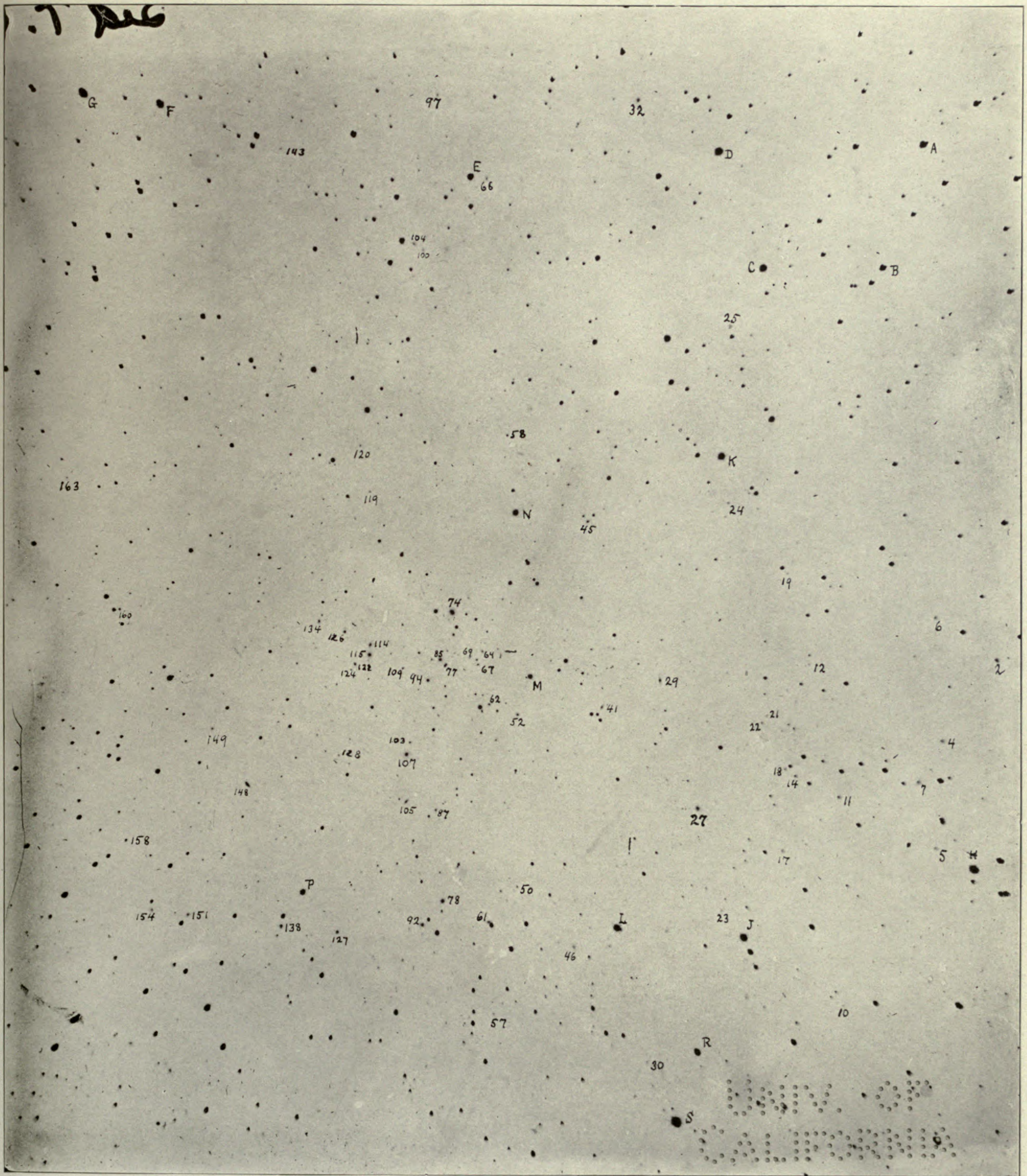
N.G.C.	α	δ	Class	Description
7604	23h11m31s.7	+6°44′48″	f	F, R, bM.
7605	32.6	6 41 46	f	F, R, bM, *15m70″p.
7586	36.1	7 54 7	f	pF, st.
7608	23 12 55.5	7 40 6	h	pF, sharp nuc., mE20° 100″×25″.
7611	23 13 16.6	7 22 45	g_0	pB, gbM, mE140°, 80″×30″.
7612	24.7	7 53 38	g	pB, mbM, cE170°, 80″×40″.
7615	35.0	7 42 58	f	F, E130°, * 14m involved.
7617	49.2	7 28 54	e	pF, pS, mbM, vlE20°.
7619	23 13 54.8	7 31 19	f	B, R, 90″d.
7621	23h14m5s.0	+ 7°40′56″	g	pF, pS, mbM, E0°.
7623	10.4	7 42 45	f	pB, R, mbM, 60″d.
7626	22.8	7 31 56	f	B, R, bM, 90″d, *14m 60″p.
7631	23 15 7.1	7 31 59	g	pB, mbM, mE80°, 110′×40″.
7634	22.3	8 12 14	f	F, R, *10m20″p.
2d I.C. 5309	23 12 51.8	7 25 32	g	pF, mbM, E0°, 50″×30″, *14m on south edge.

Yerkes Observatory
May, 1917



Wolf's Classes of Nebulae
(Copied from the Königstuhl [Heidelberg] Publications)

PLATE IV



ENLARGED NEGATIVE OF FIELD III
Center at $\alpha = 11^h 4^m$, $\delta = +29°30'$
For identification of lettered stars see page 73